Cover Crops for Organic Production Systems

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Benefits of Cover Crops

Organic Matter

Organic management systems attempt to increase soil organic matter through additions of plant biomass generated by cover cropping practices, additions of manure, compost, and other organic amendments, and conservation of crop residue. Soil organic matter enhances the formation of aggregates, which stabilizes soil and reduces runoff and erosion (Sainju et al., 1997). Increased aggregation and porosity can promote root growth by decreasing soil bulk density (weight per unit volume) and reducing resistance to root penetration. Soil organic matter improves soil tilth, reduces crusting, and increases the rate of water infiltration. Addition of organic matter to soil can also increase the populations of soil microbes, micro- and macro-arthropods, and earthworms, all of which contribute to efficient nutrient cycling and improvements in soil structure.

Roberson et al. (1991) found that cover cropping increased the heavy fraction of soil carbohydrates and increased aggregate stability. The heavy fraction carbohydrates are enriched in extracellular polysaccharides produced by soil microorganisms (Roberson et al., 1995). These extracellular polysaccharides can be described as"glue" that binds individual soil particles together in aggregates. The authors concluded that a vetch winter cover crop stimulated extracellular polysaccharide production. A small grain cover crop also stimulated polysaccharide production, but not as much as vetch.

Soil Erosion

Cover crops can help reduce soil erosion by keeping the soil covered during high rainfall periods when it might normally be bare. Soil scientists have estimated that the United States has lost 30% of its topsoil in the past 200 years due to agricultural practices that leave bare, fallow soils for a significant portion of the year (Tyler et al., 1994). Not only does erosion have long-term costs such as the loss of agricultural productivity but it also causes sedimentation of rivers, reservoirs, and estuaries, with resulting losses of aquatic habitat. Short-term costs to farmers include nutrient losses in runoff from farm fields. In a review of the literature, Langdale et al. (1991) concluded that cover crops reduced soil erosion by 62% relative to bare soil in the southeastern United States.

The extent of soil erosion control provided by cover crops during the fall, winter, and early spring depends largely upon when the crop is established. Timing is particularly important with cool season legume crops (e.g. hairy vetch, *Vicia villosa*), because late fall seeding can result in small plants with limited root systems. If the cover crop is established early, adequate growth in the fall can reduce erosion on soils that might otherwise be poorly protected. Because of its rapid growth rate in fall and continued growth during winter, cereal rye (*Secale cereale*) provides excellent erosion protection during the winter months. Use of cover crops in no-till systems provides additional erosion control because residue is left on the surface after the cover crop is killed and the following cash crop planted.

Soil Moisture Conservation

Cover crop residues help conserve soil moisture during the summer growing season by reducing water evaporation from the soil surface before full crop canopy has been established and by increasing water infiltration (Smith et al., 1987). With corn (*Zea mays*), a crop highly sensitive to moisture stress at critical stages of development, a greater reservoir of available water can substantially increase yields.

Timing cover crop kill is essential to insure that adequate soil moisture is available for early season germination and growth. If soil moisture has been depleted by an actively growing cover crop, it may be difficult to obtain good stands during dry spring seasons. Killing small grain covers 7 to 14 days before planting corn can reduce this problem (Wagger, 1989*a*). With legumes, however, early kill is likely to reduce cover crop N accumulation. When kill was delayed from early April to early May cover crop yield (hairy vetch, cereal rye, and mixtures of both) increased by an average of 160% in the Maryland Piedmont region and 83% in the Coastal Plain (Clark et al., 1994). Nitrogen contents of hairy vetch and rye-hairy vetch mixtures were 1.6 to 2 times greater by the late kill date and ranged from 65 to 100 lbs N per acre for early kill, and from 135 to 200 lbs N per acre for late kill. Growers need to monitor early spring conditions to maximize biomass production without severely depleting soil moisture before planting time. While some N production by legumes will be sacrificed, in dry years the best strategy for managing cover crops is to kill the cover crops approximately two weeks before planting (depending on weather forecasts). In most seasons, sufficient rainfall for adequate crop emergence will occur during the two-week preplant period or within the week immediately following planting. In wet years, the cover crop can be killed immediately before soil preparation (if any) and planting.

Weed Management

Cover crops can reduce weeds in subsequent cash crops. While the cover crop is growing, it can suppress the germination and growth of some early spring weeds through competition and shading (Teasdale and Daughtry, 1993). Cover crop residues remaining on the soil surface can physically modify conditions for seed germination by altering the seed environment (through changes in light availability, soil temperature, and soil moisture) and through other types of interference, primarily allelopathy (Creamer et al., 1996*a*). After cover crop dessication, it is important to prevent soil disturbance to maintain maximum soil cover from cover crop residues (Burgos and Talbert, 1996).

It is important to note that weed suppression by "smothering" will be less effective as cover crop residues decompose. Favorable climatic conditions (warm temperature, adequate moisture) and increased tillage increase the rate of residue decomposition. The rate of residue decomposition is slowed by a high C:N ratio (i.e. the relationship between the total C concentration of the residue and the total N concentration) of the residue. Mature small grain cover crops such as rye have a higher C:N ratio (~50) than do legumes such as hairy vetch (C:N ratio ≈ 12) and decompose more slowly. Mixtures of legumes and small grains are intermediate in rate of decomposition (C:N ratio ≈ 25).

Smeda and Weller (1996) found that cereal rye biomass suppressed most common annual broadleaf and grassy weeds for 4 to 8 weeks after the rye was killed. Thus, use of a rye cover crop could provide a system that eliminates the need for a soil-applied herbicide at transplanting without depressing yield. However, the authors indicated that post-emergence weed control of escaped weeds may be necessary in some years.

Rice (1974) defined allelopathy as "any direct or indirect harmful effect produced in one plant through toxic chemicals released into the environment by another". Putnam (1988) broadened this definition somewhat to include chemicals produced by actinomycetes, algae, fungi, or other microbes that may be associated with plants in the rhizosphere. Einhellig (1996) reported that allelopathic inhibition results from combinations of allelochemicals that act additively or synergistically to inhibit growth. The magnitude of the detrimental effects depends on the extent any other stresses, such as environmental conditions or biological factors (e.g. insect or disease pressure) that occur at the same time. The origin of an allelochemical is often obscure, and its biological activity may be reduced or enhanced by microbial action, oxidation, and other transformations.

Researchers have reported that the cover crops in Table have shown allelopathic effects on certain weeds. The allelopathic effects of crimson clover and hairy vetch are more apparent if the cover crop is incorporated rather than left on the surface in no-till management (Teasdale et al., 1993).

Cover Crop	Weed Suppressed	Citation
Hairy vetch	Lambsquarters, yellow foxtail Yellow nutsedge, Pitted morning glory	Teasdale et al., 1993 White et al., 1989
Crimson clover	Pitted morning glory, wild mustard, Italian ryegrass	Teasdale et al., 1993 White et al., 1989
Cereal rye	Lambsquarters, redroot pigweed, common ragweed	Barnes and Putnam, 1986 Schilling et al., 1985 Masiunas, 1995
Wheat	Morning glory, prickly sida	Liebl and Worsham, 1983
Velvetbean	Yellow nutsedge, chickweed	Hepperly et al., 1992 Fujii et al., 1992
Sorghum sudangrass	Annual ryegrass	Forney and Foy, 1985

Disease Management

Pathogens can either be enhanced, inhibited, or unaffected by cover cropping systems (Creamer et al., 1996*b*). A cover crop can act as a host for soilborne pathogens, resulting in an inoculum increase for the subsequent agronomic crop (Dillard and Grogan, 1985). Conversely, conditions for biological control of plant pathogens may be enhanced by surface residue (Phillips, 1984). Incorporated cover crop residues in some cases provided either 1) an organic food base that encourages pathogen growth (Phillips et al., 1971), or 2) organic compounds that predispose crop roots to infection by pathogens (Patrick et al., 1963). Some species, such as crucifers, can actually decrease soil pathogen populations (Lewis and Papavizas, 1971; Subbarao and Hubbard, 1996).

The impact of the cover crop on the pathogen will depend upon the nature and life cycle requirements of the pathogen. For example, if the pathogen survives best on surface residue and the cover crop residue is left on the soil surface as mulch, then pathogens may survive until the next crop is planted and the level of disease may increase (Fawcett, 1987). Many diseases are associated with surface residue, including root diseases and fungal and bacterial leaf blights (Boosalis and Cook, 1973). Conversely, increases in soil organic matter content after soil incorporation of cover crops can enhance biological control of soil-borne plant pathogens through direct antagonism and by competition for available energy, water, and nutrients (Sumner et al., 1986). Organisms that cause disease can be affected by changes in temperature, moisture, soil compaction, bulk density, and nutrient dynamics. Whether or not the cover crop is taxonomically related to the subsequent crop can also influence whether or not disease cycles are interrupted or prolonged.

Nematodes, particularly root knot (*Meloidogyne* spp.) nematodes are a major concern for crop production in the sandy soils of the southeastern USA. Because of their wide host range, it has been difficult to find rotation crops that control them (Reddy et al., 1986). Warm season legume cover crops are effective in reducing populations of some plant-parasitic nematodes. Rhoades and Forbes (1986) reported that hairy indigo and joint vetch cover crops (and mulching with clippings of cowpea (*Vigna unguiculata*)) were highly effective for maintaining low populations of *B. longicaudatus* and *M. incognita*. Rodriguez-Kabana et al. (1992) reported that velvetbean was effective in lowering population densities of several root knot species (present simultaneously) in greenhouse and field tests. Unfortunately, the latter is not always the case.

Mojtahedi et al. (1993) reported that nematode reproduction on a susceptible host varies among root knot species and among host hybridization.

Some green manure or cover crops placed in a rotation result in reductions in nematode damage by one nematode species but not in others. In a study in Florida, the warm-season legumes, pigeonpea (*Cajunus cajan*), crotalaria (*Crotalaria juncea*), hairy indigo (*Indigofera hirsuta*), velvetbean (*Mucuna deeringiana*), and joint vetch (*Aeschynomene americana*) reduced root-knot nematode damage in a following snap bean crop compared to fallow. However, they were no more effective than fallow in reducing damage from two other plant parasitic nematodes, sting (*Belonolaimus longicaudatus*) and lesion (*Pratylenchus brachyurus*) nematodes. In some cases, cover crops can be effective in reducing the population of one parasitic nematode, but serve as a host of and increase populations another parasitic nematode. While McSorley and Gallaher (1991) reported that sorghum-sudangrass cover crops reduced levels of root knot nematodes, another study reported that a sorghum-sudangrass cover crop mixture increased populations of *B. longicaudatus* and *M. incognita* (Rhoades and Forbes, 1986).

McSorley and Dickson (1995) discussed the danger of using rotation crops effective against a single key nematode parasite (e.g. *M. incognita*) when other damaging nematode pests are present in the same field (e.g. *B. longicaudatus*). They concluded that potential rotation crops should be evaluated against as many different damaging nematodes as possible, so that those that their effectiveness against (or susceptibility to) several nematode species can be recognized.

The mode of action by which some cover crops reduce population numbers of plant parasitic nematodes is unclear. Reduced root penetration as evidenced by root galling has been reported as has direct antagonism to phytopathogenic nematode species (Araya and Caswell-Chen, 1994; Kloepper et al., 1992). Rapeseed (*Brassica napus*), mustard (*Brassica nigra*) and other *Brassica spp*. have been shown to suppress a wide range of parasitic nematodes (Bending and Lincoln, 1999) and are commonly planted by organic growers as a rotation crop to "clean-up" soil during winter months.

Insect Management

Cover crops can attract both beneficial and harmful insects into cropping systems (Altieri and Letourneau, 1982; Andow, 1988). Both can disperse to cash crops when the cover crop matures or dies, and effects on insect populations will depend on the cover crop, the subsequent cash crop, and other environmental factors (Creamer et al., 1996*b*). For example, a rye cover in a tomato (*Lycopersicum esculentum*) production system decreased fruitworm (*Helicoverpa zea*) damage, but increased stinkbug (*Acrosternum hilare*) damage (Roberts and Cartwright, 1991). Prior to the arrival of important insect pests of vegetable crops, beneficial insects can be attracted into an area by the moisture, shelter, pollen, honeydew, nectar, and insect prey associated with a cover crop. They may subsist in the cover crop until the arrival of key pests and then move over into the vegetable crop to attack the pests. For example, researchers in Georgia reported high densities of big-eyed bugs (*Geocoris* spp.), lady beetles (*Coleoptera coccinellidae*), and other beneficial insects in vetches and clovers that moved into tomato crops (Bugg et al., 1990; Bugg et al., 1991). Phatak (1998) reported that assassin bugs (*Reduviidae* spp.) have destroyed Colorado potato beetle (*Leptinotarsa decemlineata*) feeding on eggplant (Solanum m*elongena*) planted into strip-tilled crimson clover.

Nitrogen Fixation

Leguminous cover crops can "fix" significant amounts of N for use by subsequent crops. Through a symbiotic association with legumes, Rhizobia bacteria convert atmospheric N_2 into an organic form that the legume uses for growth. Growers that plant leguminous cover crops before cash crops can reduce the N recommendation on the NCDA soil test report. Non-leguminous cover crops, typically grasses or small grains, do not fix N_2. Nonetheless, they can be effective in recovering mineral N from soil after crops are harvested. Plant available N that might otherwise be lost to leaching or runoff during the fall and winter months is retained as "biomass N" (Kuo et al., 1995; McCracken et al., 1994). Generally, biomass N in mature small grain cover crops (desiccated in April and May) will not be available to crop plants in the following season. Tables 1 and 2 report aboveground biomass, and aboveground biomass-N production data of various winter and summer cover crops, respectively planted in North Carolina.

Cover crop biomass and N accumulation depend on the length of the growing season, local climate, and soil conditions (Shennan, 1992). For individual species, the variation in the proportion of total plant N derived from N fixation can vary widely and has been found to be dependent upon water supply, inoculation, crop rotation, tillage, applications of fertilizer N, and soil fertility factors such as P availability and soil pH (Peoples and Craswell, 1992). Therefore, the proportion of total plant N derived from residual soil N (or fertilizer N) can vary widely as well, and would depend on these same factors.

While most reports on N accumulation refer to aboveground biomass, fallen leaves, roots, and nodules may also provide N for subsequent crops. Chapman and Myers (1987) estimated that nodulated roots can contribute 12 to 33 lbs N per acre to crop N yield. Leaf fall during legume development can contain up to 35 lbs N per acre (Bergersen et al., 1989). Although roots and leaf fall can contribute N to the potentially available soil N pool, in most circumstances this contribution varies and is difficult to calculate. Therefore, the N credit provided by cover crops is normally estimated by the live crop biomass present and the N concentration of this biomass when the cover crop is killed. The portion of total cover crop N that is contained in the aboveground biomass is approximately 75% for cereal rye, 90% for hairy vetch, and 80% for crimson clover (Shipley et al., 1992).

Nitrogen Mineralization

When grass or legume cover crops are killed (chemically or by tillage), soil microorganisms decompose the plant residue. In a process called mineralization, soil microbes convert organic N to ammonium (NH_4^+) and then to nitrate (NO_3^-) compounds, the forms of N that plant roots assimilate.

During the past decade, agronomists have attempted to characterize patterns of N release from cover crops. One of the most common and reliable predictors of N release (mineralization) from organic materials and plant residues is the ratio of carbon to nitrogen (C:N) (Hargrove, 1991; Ranells and Wagger, 1992). In the southeastern U.S., legume cover crops such as hairy vetch and crimson clover desiccated immediately prior to corn planting generally have C:N ratios of 10:1 to 20:1 (Ranells and Wagger, 1997). As a general rule, cover crop amendments with C:N ratios lower than 25:1 will release N quickly, and this was the case in the example above (Wagger, 1989*b*). Residues with C:N ratios greater than 25:1 such as cereal rye and wheat generally decompose slowly. At ratios greater than 25:1, and without sufficient residual or fertilizer N, soil microorganisms will immobilize soil N (from both the organic and inorganic N pools). In effect, When soil microbes and crops compete for the same available N supply, soil microbes have a distinct competitive advantage. If immobilization exceeds mineralization, there may be a temporary N deficit in a following crop.

Legumes have relatively low C:N ratios (less than 25:1), and although some immobilization occurs as microbial biomass increases, the net effect is for mineralization to exceed immobilization and plant available N to increase in soil after incorporation of the legume. In fact, legume N can be quickly mineralized, perhaps even before the subsequent crop has a high demand for it. If available N exceeds the crop needs, it can be subject to leaching losses. In contrast, mature grass cover crops generally have C:N ratios greater than 25:1, resulting in N immobilization.

Nitrogen release from crimson clover, hairy vetch, and cereal rye cover crops was examined by Wagger (1989*b*) and results indicated greater N release from residues with narrower C:N ratios. The author reported that 75 to 80% (71 to 85 lbs N per acre) of hairy vetch and crimson clover residue N was released (mineralized) eight weeks after killing the cover crops. However, not all of the released N was taken up by the following corn crop, which utilized approximately 50% of the N released by both residues. (In this case, the 50% value may be considered the N uptake efficiency of corn from legume residues. This value is similar to the N uptake efficiency of corn from inorganic fertilizer sources such as ammonium nitrate). The author also reported that 50% (21 lbs N per acre) of rye residue N was released eight weeks after dessication, but that none of it was taken up by the following corn crop. Instead, the N was immobilized in microbial biomass. In the present study, this N tie-up was alleviated with the addition of fertilizer N.

Timing of cover crop kill can affect this synchrony of N mineralization and crop N requirements. Generally, more mature cover crops have higher C:N ratios and slower decomposition rates (Wagger, 1989*a*). In this study, cover crops desiccated in mid-April decomposed faster than those desiccated in early May. The percentage of initial residue remaining after 16 weeks for the early and late dessication dates is presented in Table 3. The second year was characterized by a relatively dry growing season, which slowed decomposition. Estimates of N released from each cover crop indicated that the potentially larger available N pool resulting from a delay in dessication was offset by the slower rate of N release, especially for rye and crimson clover. In another study, Ranells and Wagger (1992) harvested crimson clover in the spring at four growth stages. As crimson clover matured from late vegetative to early seed set growth stages, dry matter production increased from 2,000 to 5000 lbs/acre, and N concentration declined by 30% (as a consequence of the increase in biomass). Results indicated that allowing crimson clover to attain the late bloom stage prior to dessication and planting of the summer crop optimized clover top-growth N content and subsequent N release.

Nutrient Cycling and Crop Rotations

Because of increased soil biological activity associated with use of legume cover crops, N cycling within the plant-soil system takes place more quickly than in production systems that rely solely on inorganic N sources to meet crop N needs (Radke et al., 1988).

Planting a non-leguminous winter cover crop after a summer crop can “trap” or assimilate “leftover”, residual soil nitrogen through cover crop uptake and reduce the potential for N losses from leaching or runoff (Shipley et al., 1992; Ditsch et al., 1993; Power and Doran, 1988). For example, Wyland et al. (1996) reported a 65 to 70 percent reduction in nitrate leaching from cover cropped plots compared with a fallow control during winter, because plant roots removed N and water that would have otherwise been lost from the soil profile. Generally, grass monocultures are more effective than legume monocultures in recovering soil mineral N. Ranells and Wagger (1992) reported that a rye monoculture reduced soil inorganic N content an average of 62% and 37% in two successive years, compared to legume monocultures. Reductions by grass/legume mixtures were greater than legume but small than grass monocultures. Clark et al. (1994) reported that a cereal rye-hairy vetch biculture successfully scavenged potentially leachable

N while maintaining corn yields by adding fixed N to the cropping system. Additionally, the cover crop utilized excess water in the soil, which also helped limit leaching losses.

Choosing a Cover Crop

Generally, cover crop selection is based on individual enterprise or production goals. For example, if the purpose of a cover is to provide readily available, biologically fixed N for subsequent crops, then the grower should choose a legume such as hairy vetch or cowpea. If the cover crop will be managed as a surface mulch for weed suppression or incorporated to improve soil quality, then the grower should choose a grass cover crop such as cereal rye or sorghum-sudangrass. Both of these grass cover crops can produce large amounts of biomass with high C:N ratios at maturity, and both are reported to suppress (some) weeds.

Monocultures vs. Mixtures

Mixtures of cover crop species can be planted to optimize the benefits associated with cover crop use. Grass species establish ground cover more quickly than legume monocultures, and roots are more physiologically active in autumn (Ranells and Wagger, 1997). Mixtures that include grasses can therefore more effectively prevent soil erosion and reduce soil N concentration. Competition for soil N in mixed stands can also result in increased biological N fixation by the legume.

Grass and legume species grown in biculture generally result in greater dry matter yields per unit area than the respective monocultures (Roberts and Olson, 1942; Holderbaum et al., 1990; Sullivan et al., 1991). Aboveground cover crop biomass N content can be increased with a mixture that is spatially more efficient in utilization of nutrients and water (Haynes, 1980; Ofori and Stern, 1987). For example, a deep-rooted cover crop that is grown with a shallow rooted cover crop can utilize water and resources throughout more of the soil profile. A greater leaf area is exposed to sunlight, increasing photosynthetic efficiency.

Nitrogen cycling can also be manipulated with mixed cover crop species. Combining plants with high C:N ratios (mature cereals) with plants that have low C:N ratios (legumes) can influence mineralization of cover crop residues. Theoretically, decomposition proceeds at a faster rate compared to a grass monoculture, while moderating the more rapid N mineralization potential of a legume (Ranells and Wagger, 1997). The release of N from residues can be more synchronous with subsequent crop uptake by moderation of N immobilization processes and large flushes of nitrate. This can help to optimize the efficiency with which fixed N is used by subsequent crops.

Planting mixtures of cover crops can take advantage of the allelopathic potential of the cover crops to suppress weeds. Allelopathic suppression of weeds has been shown to be a species specific phenomenon, therefore a broader spectrum of weed control may be possible by growing a mixture of cover crop species, each contributing allelopathic activity towards specific weed species (Creamer and Bennett, 1997). Mixtures can also be planted to influence insect populations. Cover crop species, regardless of biomass or biomass N production potential, could be included a mixture if they were known to attract important beneficial insects into the cropping system.

Measuring Cover Crop Nitrogen

Biomass production of cover crops depends upon geographic location, climatic conditions, and stage of growth at “harvest”. An ultimate goal of a grower using cover crops as a green manure is to predict the amount of nutrients in the cover, the percentage that will decompose during the subsequent cropping season, and then determine if additional nutrients will be required to achieve the expected crop yield. This prediction normally requires three measurements: the amount of biomass (dry weight), the nutrient composition of the cover crop, and the decomposition rate of the cover crop during the subsequent cropping season.

Growers can estimate the amount of N in a cover crop by assessing the total biomass yield of the cover crop and the percentage of N in the plants when they're killed. A simple process for the assessment is explained in Managing Cover Crops Profitably (Sarrantonio, 1998). That process is reproduced below.

To estimate yield, take cuttings from several areas in the field. Dry and weigh the samples. Use a yardstick or metal frame of known dimensions and clip the plants at ground level within the known area. Dry the samples in an oven at about 140°F for 24 to 48 hours until they are "crunchy dry". Use the following equation to determine per acre yield of dry matter:

$$\text{Yield (lbs/acre)} = \frac{\text{Total weight of dried samples (lb)}}{\text{Area (ft}^2\text{) sampled}} \times \frac{43{,}560\ \text{ft}^2}{1\ \text{Acre}}$$

For example, two 3 feet X 3 feet (9 ft^2 or 1 yd^2) samples weigh 2.5 pounds. The dried "biomass" yield equals:

$$\text{Yield (lbs/acre)} = \frac{2.5\ \text{lb}}{18\ \text{ft}^2} \times \frac{43{,}560\ \text{ft}^2}{1\ \text{ac}} = 6{,}050\ \text{lbs/acre.}$$

Though not as accurate, yield can be estimated from the height of the cover crop and its percent groundcover. At 100% groundcover and 6-inch height, most non-woody legumes contain roughly 2,000 lbs/acre of dry matter. For each additional inch, add 150 lb.

For example, a hairy vetch cover crop is 18 inches tall and has 100% groundcover. The first six inches of dry biomass weighs roughly 2000 pounds. The 12 additional inches of growth weigh 150 pounds per inch. The additional weight is:

$$12 \times 150 = 1800 \text{ lb},$$

and the total weight of the cover crop dry matter is:

$$2000 + 1800 = 3800 \text{ lb}.$$

If the stand has less than 100% groundcover, multiply the total weight by the percent groundcover represented as a decimal (i.e., percent/100). If the percent groundcover in the example above is 60 percent, then the weight of dry matter is:

$$3800 \times 0.60 \text{ (i.e., } 60/100) = 2280 \text{ pounds of dry biomass.}$$

For cereal rye, the height relationship is a bit different. Cereal rye weighs approximately 2000 lbs/acre of dry matter at an 8-inch height and 100 percent groundcover. For each additional inch, add 150 pounds, as before, and multiply by the percent groundcover represented as a decimal (i.e., percent/100). For most small grains and other annual grasses, start with 2000 lbs/acre at 6-inches and 100 percent groundcover. Add 300 pounds for each additional inch and multiply by the percent groundcover represented as a decimal (i.e., percent/100).

Annual legumes typically have between 3.5 and 4.0% N in the aboveground biomass prior to flowering, and 3.0 to 3.5% at flowering. After flowering, N in the leaves decreases quickly as it accumulates in the growing seeds. Most cover crop grasses contain 2.0 to 3.0% N before flowering and 1.5 to 2.5% after flowering. Other cover crops, such as Brassica species and buckwheat, will generally be similar to, or slightly below, grasses in their N concentration. To precisely determine the percent N in the cover crop, send a plant sample to a laboratory for a chemical analysis. The NCDA Plant Analysis lab provides that service for $4.00 per sample.

To calculate the amount of N in the dried cover crop biomass, multiply the dry biomass yield times the percent N expressed as a decimal, (i.e., N% ÷ 100). For the hairy vetch cover crop example above with 100 percent cover and an estimated 4% N at flowering:

Total N (lbs/acre) = 3800 lbs/acre X .04 (i.e., 4 ÷ 100) = 152 lb N per acre.

As discussed previously, not all of the N contained in the cover crop residue will be available to the following crop. To conservatively estimate the amount that will be available to the following crop, multiply legume biomass N calculated above by 0.50 if the cover crop residue will be incorporated and by 0.40 if the residue will be left on the soil surface. Remember that little, if any, N will be available to the following crop from a mature small grain cover crop. From the example above, if the hairy vetch is incorporated in the soil in early May in a normal spring, then the N available from the hairy vetch to the next crop will be:

Available N (lbs/acre) = 152 lbs N per acre X .50 = 76 lbs N per acre.

If the hairy vetch is left on the soil surface in early May in a normal spring, then the N available from the hairy vetch to the next crop will be:

Available N (lbs/acre) = 152 lbs N per acre X .40 = 61 lbs N per acre.

These "availability coefficients" will change, depending on the weather. In dry or cold and wet springs, the soil microorganisms responsible for mineralization of the organic N in the cover crop residue will be less active. The mineralization rate will be reduced, and a lesser fraction of the N will be available to the following cash crop.

Cover Crops for North Carolina

Winter and summer legume and grass cover crops that perform well in North Carolina are described below. Sketches of each crop are drawn from Duke (1981), Sarrantonio (1994), Bowman et al. (1998), and the University of California at Davis Sustainable Agriculture Cover Crop Resource Page at http://danr010.ucdavis.edu/ccrop/ (UCD, 2001). For more information on the cover crops listed, or to find information about other potential cover crops, refer to these references.

Appropriate Winter Species

Winter legume cover crops best adapted to North Carolina soil and climatic conditions are crimson clover, hairy vetch, Austrian winter pea (*Pisum sativum arvense*), and subterranean clover (*Trifolium subterraneum*). Cereal rye, wheat, and oats are also commonly used as small grain cover crops and in mixtures with the legumes mentioned above. Generally, winter cover crops are planted in early fall and allowed to grow until mid-spring, at which time the crop is incorporated by tillage, or killed and left as a surface mulch into which another crop is planted.

Legumes

Hairy Vetch (*Vicia villosa*): Hairy vetch forms a very dense cover, and if planted with a tall growing species like rye, will climb and produce a great deal of biomass. Hairy vetch is probably the most commonly used cover crop in the United States, in part, because it is so widely adapted. Hairy vetch is seeded at 20 to 30 lbs/acre; with a lower rate used if the vetch is drilled or planted in mixtures. At mid-bloom, hairy vetch can be easily killed by undercutting or mowing. Hairy vetch can harbor nematodes [root knot (*Meloidogyne* spp.) and soybean cyst (*Heterodera glycines*)] and various cutworms. Susceptible vegetable crops should be temporally separated in a rotation. If allowed to produce mature seed, vetch can become weedy in subsequent crops.

Crimson Clover (*Trifolium incarnatum*): Crimson clover has an upright growth habit and blooms about 3 to 4 weeks earlier than hairy vetch. It grows vigorously in fall and winter and has good reseeding ability (depending on cultivar). Crimson clover has good shade tolerance and can be overseeded into fall vegetable crops in September. Seeding rates vary from 15 to 25 lbs/acre, with the lower rate being used when the seed is drilled.

Subterranean Clover (*Trifolium subterraneum*): Subterranean clover is a relatively low growing winter annual with prostrate stems. In late spring, subterranean clover develops seeds below ground (much like peanut), which gives it an excellent reseeding ability. Subterranean clover forms a thick mat when left on the surface as a mulch, and has been shown to suppress weeds in vegetable crops planted into the mulch. Subterranean clover does not produce as much biomass as other cool-season legumes grown in the South, but biomass yield can reach 5,400 lbs/acre with N concentration between 2 and 3 percent. Subterranean clover can be seeded at 8 to 15 lbs/acre between mid-September and mid-October.

Austrian Winter Pea (*Pisum sativum arvense*): Austrian winter pea is succulent and viney and can climb when planted with support crops. It grows vigorously and will suppress weeds while growing, but it decomposes rapidly and would not be a good choice for a surface mulch for weed control. Austrian winter pea does well in a mixture with oats, barley, rye, or wheat. Seeds are drilled at 60 to 90 lbs/acre and can be sown through October.

Cahaba White Vetch (*Vicia sativa*): Also know as common vetch, this legume is tolerant of a wide range of soil conditions. In North Carolina it does not produce as much biomass and accumulate as much N as hairy vetch because it's not as winter hardy. It is susceptible to nematodes, and honeybees are not particularly attracted to its large blooms. Common vetch taproots can extend 3 to 5 feet deep in well-drained soils.

Nonlegumes

Cereal Rye (*Secale cereale*): Rye is one of the most commonly used winter cover crops. It grows 3 to 6 feet tall and has an extensive, fibrous root system. It is excellent mixed with hairy vetch, which will use it for climbing support. Rye can tolerate a wide variety of soil types and climatic conditions and is considered to be weed suppressive when managed as a mulch. Of all the small grains, rye is the best scavenger of excess soil N in the fall. The seeding rate is 100 lbs/acre.

Annual Ryegrass (*Lolium multiflorum*): Annual ryegrass is a non-creeping bunchgrass. In the spring it can grow 2 to 4 feet tall if not cut. Annual ryegrass can be difficult to control and can also become a serious weed if it produces seed. Ryegrass can require considerable N and water, so if these are limiting it may not be a good choice. Ryegrass has a very fibrous and dense root system and can protect against soil erosion while improving water infiltration and soil tilth. Dry matter yield can average between 1,300 and 2,000 lbs/acre, with an average N content of 1.5%. Normally seeded in the fall, seeding rates are between 20 and 30 lbs/acre.

Other cereal grasses: Wheat (*Triticum aestivum*) provides a good ground cover over the winter and also provides the option of harvesting the grain. Barley (*Hordeum vulgare*) biomass production reaches a maximum about two weeks earlier than wheat, about the same time as crimson clover. Barley, grown as a smother crop, has been shown to suppress winter annual weeds in cropping systems, but must be planted in September or early October to reduce winterkill. Oats (*Avena sativa*) grow well in cool weather and provide rapid ground cover in the fall. Some growers plant spring oats in the fall to produce a winter killed mulch for early spring no-till vegetable plantings. However, the spring oats may not winter kill in the Coastal Plain or in mild winters. All of the cereal grasses will produce biomass ranging from 2,000 to 6,000 lbs/acre (Table 1) with N concentrations between 1% and 2%. Biomass accumulation is in part dependent on how early in the spring the cover crop growth is terminated. The high end of the range represents a kill date in mid to late May. At this late date, however, the biomass C:N ratio will normally be greater than 50:1, and one would expect an immobilization of any mineralized N by soil microbes. Small grains are normally drilled at 100 pounds of seed per acre.

Appropriate Summer Cover Crops

There is growing interest in the use of short-season summer annual legumes or grasses as cover crops and green manures in vegetable production systems. Summer annual legumes and grasses can provide benefits in the period between harvest of spring vegetable crops and planting of fall vegetables or small grains. Summer cover crops can provide N for subsequent crops, reduce erosion, runoff, and potential pollution of surface waters, capture soil N that might otherwise be lost to leaching, add organic matter to the soil, improve soil physical properties, impact insect and disease life cycles, and suppress nematode populations and weed growth. While additional legumes and grasses are being evaluated for use in North Carolina, the following species are currently the best options.

Legumes

Cowpea (*Vigna unguiculata*): Other common names for this plant are blackeye, crowder, and southern pea. Cowpea is a fast growing, summer cover crop that is adapted to a wide range of soil conditions. Cowpeas have a deep taproot, are drought tolerant, and compete well against weeds. Cowpeas produce 3,000 to 4,000 lb dry biomass per acre, which contains 3 to 4 percent N. Maximum biomass is achieved in 60 to 90 days. Residues are succulent and decompose readily when incorporated into the soil. Cowpeas can be planted in the spring (after all danger of frost), through late summer. Cowpea seed can be drilled in rows 6 to 8 inches apart at 40 lbs/acre or broadcast at approximately 75 lbs/acre. Higher seeding rates are necessary in late summer when soil moisture is likely to be limiting. Recommended cultivars include ‘Iron Clay’ and ‘Red Ripper’. Plants normally grow up to 24 inches tall, but some cultivars can climb when planted in mixtures with other species. Good mixture options are sorghum-sudangrass and German foxtail millet. When mowed or undercut, cowpeas can have considerable regrowth in some years.

Soybean (*Glycine max*): Soybean is one of the best economical choices for a summer legume cover crop. It is an erect, bushy plant that grows 2 to 4 feet tall, establishes quickly, and competes well with weeds. When grown as a green manure crop, late maturing cultivars usually give the highest biomass yield and fix the most N. While most of the roots are in the top 8 inches of the soil, some roots can penetrate up to 6 feet deep. If well established, soybean will withstand short periods of drought. The viney, forage types (e.g., cultivars 'Quailhaven' and 'Laredo') have the potential to produce more biomass than traditional soybean cultivars.

Velvetbean (*Mucuna deeringiana*): Velvetbean is a vigorously growing, warm season annual legume native to the tropics and well adapted to southern U.S. conditions. It performs well in sandy and infertile soils. Most cultivars are viney and some can attain a stem length of 10 meters. Velvetbean is an excellent green manure crop, producing high amounts of biomass that decomposes readily to provide N for a subsequent crop. Velvetbean does best when direct seeded into warm soils in 38-inch rows. Velvetbean seed should not be drilled, because the very large seed can be damaged in conventional drills. When grown for seed, velvetbean should be sown in a mixture with an upright crop like sorghum sudangrass or corn. Velvetbean vines will climb stems of these grasses, and flowers produced will get necessary air circulation.

Sunnhemp (*Crotalaria juncea*): Sunnhemp is a tall, herbaceous, warm season annual legume with erect fibrous stems. It has been used extensively for soil improvement and green manuring in the tropics and is competitive with weeds. It grows rapidly and can reach a height of 8 feet in 60 days. It can tolerate poor, sandy, droughty soils and requires good drainage. Sunnhemp tolerates moderate alkalinity, and a soil pH below 5 can limit growth. Sunnhemp is seeded in rows 38 inches apart at 30 lbs/acre. Higher seeding rates can lead to succulent stems and lodging, and are only recommended if the crop will be grown for only 4 to 5 weeks. The growing season in North Carolina is not long enough to produce viable seed. Sunnhemp becomes fibrous with age, but the plants will remain succulent for about 8 weeks after seeding. It can be integrated into cropping systems by sowing it in mid-summer after cool-season vegetable or sweet corn harvest, and will produce high biomass yields and N in the months before frost. Seed is not readily available currently, but availability may increase if demand increases. While forages of some *Crotalaria* species are toxic to animals, sunnhemp forage is not. Sunnhemp should not to be confused with showy crotalaria, a noxious weed species in North Carolina.

Nonlegumes

Buckwheat (*Fagopyrum esculentum*): Buckwheat is a very rapidly growing, broadleaf summer annual, which can flower in 4 to 6 weeks. It reaches 30 inches in height and is single-stemmed with many lateral branches. It has both a deep taproot and fibrous, superficial roots. It can be grown to maturity between spring and fall vegetable crops, suppressing weed growth and recycling nutrients during that period. Buckwheat flowers are very attractive to insects, and some growers use this cover as a means to attract beneficial insects into cropping systems. Buckwheat is an effective phosphorous scavenger. It is succulent, easy to incorporate, and decomposes rapidly. The main disadvantage to buckwheat is that it sets seed quickly and if allowed to go to seed, it may become a weed problem in subsequent crops. Thus, the optimal time to incorporate buckwheat is one week after flowering, before seed is set. Buckwheat can be planted anytime in the spring, summer or fall, but is frost-sensitive.

Sorghum sudangrass (*Sorghum bicolor X Sorghum sudanense*): Sorghum sudangrass is a cross between grain sorghum and sudangrass. It is a warm-season annual grass, most often planted from late spring through mid-summer. It grows well in hot, dry conditions and produces a large amount of biomass. Often reaching 6 feet in height, it can be mowed to enhance biomass production. Sorghum sudangrass is very effective at suppressing weeds and has been shown to have allelopathic properties. The roots of sorghum sudangrass are good foragers for nutrients (especially N) and help control erosion. Sorghum sudangrass does well when planted in mixtures, providing effective support for viney legumes like velvetbean. If frost-killed, the residue can provide a no-till mulch for early planted spring crops like broccoli.

German (foxtail) millet (*Setaria italica*): German or foxtail millet is an annual warm season grass that matures quickly in the hot summer months. It is one of the oldest of cultivated crops. Although German millet has a fairly low water requirement, because of its shallow root system, it doesn't recover easily after a drought. Grain formation requires 75 to 90 days. German millet forms slender, erect, and leafy stems that can vary in height from 2 to 4 feet. The seed can be drilled from mid-May through August at a rate of 10 to 15 lbs/acre. A small seeded crop, German millet requires a relatively fine, firm seedbed for adequate germination. In order to avoid early competition from germinating weed seed, it should be sown in a stale seedbed or closely drilled in the row. Coarse, sandy soils should be avoided.

Pearl Millet (*Pennisetum glaucum*): Pearl millet is a tall summer annual bunchgrass that grows 4 to 10 feet tall. It is also often referred to as cattail millet because its long dense spike-like inflorescences resemble cattails. Though it performs best in sandy loam soils, pearl millet is well adapted to sandy and/or infertile soils. Pearl millet can be planted from late April through July at a rate of 15 to 20 lbs/acre. Pearl millet matures in 60 to 70 days. In North Carolina studies, pearl millet was not as readily killed by mechanical methods (mowing and undercutting) as German or Japanese millet.

Japanese Millet (*Enchinochloa frumentacea*): Japanese millet is an annual grass that grows 2 to 4 feet tall. It resembles and may have originated from barnyard grass. Japanese millet is commonly grown as a late-season green forage. If weather conditions are favorable, it grows rapidly and will mature seed in as little as 45 days. Japanese millet can be planted from April to July at a rate of 10 to 15 lbs/acre. It performs poorly on sandy soils.

Establishment of cover crops

Table 4 lists the preferred planting dates for winter cover crops in North Carolina. Tables 5 and 6 list Management Guidelines for Winter and Summer Cover Crops, respectively.

Although crimson clover, hairy vetch, Austrian winter pea, and common vetch are widely adapted to North Carolina soil and climatic conditions, there are some limitations. Hairy vetch tends to be more winter hardy than the other winter legumes and can generally be planted later. Hairy vetch is also better adapted to sandy soils than crimson clover, although crimson clover will provide adequate dry matter production on most well drained, sandy loams. In contrast, crimson clover grows faster in the spring, thereby maturing and obtaining peak dry matter production approximately three to four weeks before hairy vetch. Adequate dry matter and nitrogen production will be obtained with a soil pH from 5.8 to 6.0. Soil testing will help determine P and K fertilizer requirements. It is important to inoculate legumes with the proper strain of N-fixing bacteria.

Drilling into a conventional seedbed is the most reliable way to obtain a uniform stand. However, a no-till grain drill can also be used successfully, provided that the residue from the previous crop is not excessive and the soil is moist enough to allow the drill to penetrate to the desired planting depth. Seeds may be broadcast if the soil has been disked and partially smoothed. Cultipack after broadcasting to firm the soil around the seeds. In a limited number of trials, aerial seeding into a standing crop, such as soybeans, has proven successful. Crimson clover, in particular, can be established quite easily with this method. An innovative system that has shown promise in North Carolina and other southeastern states is to allow crimson clover to reseed itself naturally. This method should work in North Carolina, even where corn is the following crop (Ranells and Wagger, 1993).

Cover Crop Residue Management

In organic systems, cover crops may be destroyed by tillage, mowing, undercutting, or rolling. In a wet growing season, incorporating legumes may produce the highest yields. However, under relatively dry growing conditions, legume residue left on the surface helps conserve soil moisture and yields are higher with conservation tillage.

In no-till organic production systems, cover crops are normally killed mechanically and left on the surface as a mulch. Of the three methods for mechanically killing cover crops, undercutting, mowing, and rolling, the first is the most effective. An undercutting implement utilizes a steel bar that is drawn several inches underneath the soil surface (usually beneath a plant bed), severing the top growth and crown of the plant from the roots, and leaving the surface and aboveground biomass undisturbed. Mowing with a flail mower leaves the finely chopped residue evenly distributed over the bed, and, unless packed well, the residue tends to decompose quickly. Rolling the cover crop damages the plants by lodging them severely and by successive crimping of cover crop stems. Rolling keeps the above ground part of the plant attached to the root system. Rolled plants decompose more slowly than those killed by mowing and, consequently, control weeds for a longer period of time (Lu et al., 2000).

The procedures for planting without tillage into a cover crop are similar to those used when planting into residues of a previous crop such as soybeans or corn. Please refer to the chapter, “Tillage in Organic Farming Systems” for more information about managing cover crop biomass.

Economics

Research investigating the profitability of cover crops in horticultural systems is still in the beginning stages. Many more years of data are required to evaluate the long-term profitability of cover crops in horticultural systems. Increased profitability from use of cover crops is generally attributed to a reduction of inputs such as N fertilizer, herbicides, reduced costs of pest and disease control, and reduced tillage operations. A review of work recently completed suggests that reducing input costs with cover crops may not be enough to increase profitability, and that it appears that crop yields must also be enhanced (Lu et al., 2000). In two studies where cover crops were found to be unprofitable, crop yields for the cover crop systems were lower than those for the conventional systems (Creamer et al., 1996*b*; Brunson et al., 1995). In studies where cover crops were found to be more profitable than conventional systems, reduced input costs were accompanied by enhanced yields (Nwonwu and Obiaga, 1988; Kelly et al., 1995).

With regard to agronomic (grain) crops, the most important factors affecting the relationship between the costs of establishment of cover crops to the benefits derived from them are their ability to enhance crop yields and to reduce crop establishment costs (Lu et al., 2000). Legume cover crops such as hairy vetch and crimson clover are generally reported to be more profitable than grass cover crops such as rye or wheat due to the ability of legumes to contribute N to the following crop, reducing required N inputs (Roberts et al., 1998). Grass cover crops may in fact consume N that could be utilized by the following crop. Including legume cover crops in grain cropping systems may also reduce the energy required for crop production (Ess et al., 1994). Other studies have indicated hairy vetch systems are the most profitable cover crop systems, not because of reduced N application and energy savings (reductions in input costs), but because hairy vetch mulch improves soil structure and water-holding capacity and thus increases the effectiveness of applied N (Lichtenberg et al., 1994; Hanson et al., 1993).

These benefits, however, may not always lead to increased profits for farmers. Allison and Ott (1987) reviewed studies investigating the economics of using legume cover crops in conservation tillage systems. The authors concluded that legume cover crops are profitable if they enhance the yield of the succeeding crop but are unprofitable if used as the sole source of N in the cropping system. They further concluded that N prices would have to increase considerably for legume cover crops to become cost-effective N sources. In studies where cover crop systems are reported to be less profitable than conventional systems, the lower profitability is attributed to the establishment cost of the cover crop. In these studies, the benefits of using the cover crop system (increased yields, reduced N applied) do not outweigh the establishment cost of the cover crop (Bollero and Bullock, 1994; Hanson et al., 1993).

Growers must determine for themselves whether the less apparent, long-term benefits, such as reduced soil erosion, increased organic matter content, improved soil physical properties, reduced nitrate leaching, and enhanced nutrient cycling provide additional economic value to cover cropping.

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Table 1. Winter Cover Crop Production

	Aboveground Biomass[1]	Aboveground Biomass N[2]	C:N
Legumes	lbs $acre^{-1}$	lbs $acre^{-1}$	
Crimson Clover	4000 - 5000	50 - 140	16
Hairy Vetch	5000 - 6000	80 - 200	11
Cahaba White Vetch	4000 - 5000	60 - 150	20
Austrian Winter Pea	4000 - 5000	60 - 180	21
Subterranean Clover	3500 - 4500	60 - 150	14
Non-legumes			
Cereal Rye	6000 - 8000	30 - 65	40
Annual Ryegrass	2000 - 3000	30 - 65	25
Barley	4000 - 5000	20 - 45	20
Wheat	5000 - 6000	20 - 45	35
Oats	4000 - 5000	20 - 45	35
Mixtures			
Crimson/Rye	6000 - 8000	80 - 140	26
Hairy Vetch/Rye	6000 - 8000	80 - 180	18

[1]dry matter

[2]mean

Table 2. Summer Cover Crop Production

	Aboveground Biomass[1]	Aboveground Biomass N[2]	C:N
Legumes	lbs $acre^{-1}$	lbs $acre^{-1}$	
Cowpeas	2500 - 6000	60 - 90	21
Sunnhemp	6000 - 8000	80 - 160	23
Soybean	3000 - 5000	50 - 105	20
Velvetbean	1500 - 6000	20 - 70	21
Lab Lab	1500 - 3000	20 - 45	29
Non-legumes			
Sorghum sudangrass	8000 - 10000	65 - 100	53
Sudangrass	6000 - 8000	50 - 65	44
Japanese Millet	3000 - 4000	25 - 45	42
Pearl Millet	5000 -8000	45 - 90	50
German Foxtail Millet	3000 - 4000	30 - 55	44
Buckwheat	2000 - 3000	15 - 40	34
Mixtures			
Soybean/J. Millet	3000 - 5000	30 - 100	28
Cowpea/S. Sudangrass	7000 - 8000	65 - 135	33

[1] dry matter [2] mean

Table 3. Percent of initial cover crop residue remaining after 16 weeks with April and May kill dates

	1984		1985	
	April	May	April	May
Rye	53	56	59	94
Crimson clover	14	30	42	57
Hairy vetch	13	19	35	49

Table 4. Preferred planting dates for winter annual legumes and small grains

Legumes	Mountains	Piedmont	Coastal Plain
Crimson clover	8/10 to 9/10	8/25 to 9/15	9/1 to 9/30
Hairy vetch	8/10 to 9/10	8/25 to 9/30	9/1 to 9/30
Subterraneum clover	8/10 to 9/10	8/25 to 9/15	9/1 to 9/30
Austrian winter pea	8/10 to 9/10[b]	8/25 to 9/15	9/1 to 9/30
Cahaba white vetch	Not adapted	Not adapted	9/1 to 9/30
Extended seeding date[a]	10/1	10/25	10/30

Small grains	Mountains	Piedmont	Coastal Plain
Rye	8/15 to 9/15	9/15 to 10/15	9/30 to 11/15
Wheat	8/15 to 9/15	9/15 to 10/15	9/30 to 11/15
Oats	Not adapted	9/15 to 10/15	9/30 to 11/15
Extended seeding date	10/15	11/15	12/15

[a]Seeding is possible until this date but not preferable. Successful establishment and production will vary with environmental conditions. Some erosion control will be lost at later planting dates.

[b]Freeze damage may occur above 2,500 ft. elevation

Table 5. Management Guidelines for Winter Cover Crops

	Seeding Rate[1]		Seed Depth[2]
	Drilled	Broadcast	
Legumes	lbs		inches
Crimson Clover	15 - 20	20 - 25	¼ - ½
Hairy Vetch	15 - 20	20 - 30	½ - 1½
Cahaba White Vetch	20 - 30	25 - 40	½ - 1½
Austrian Winter Pea	60 - 90		¾ - 1 ½
Subterranean Clover	8 - 15	10 - 20	¼ - ½
Non-legumes			
Cereal Rye	100	120	1 - 2
Annual Ryegrass	20-30	30-40	¼ - ½
Barley	100	140	1 - 2
Wheat	100	120	1 - 2
Oats	100	130	1 - 2
Mixtures			
Crimson/Rye	15/40	20/60	¼ - ½
Hairy Vetch/Rye	20/40	20/60	½ - 1

[1]If broadcasting seed or planting late in the fall, use the higher rate.

[2]Use shallow depth in clayey soils, deeper depth for sandy soils or droughty conditions

Table 6. Management Guidelines for Summer Cover Crops

	Seeding Rate		Seed Depth
	Drilled	Broadcast	
Legumes	lbs		inches
Cowpeas	40	70 - 100	½ - 1½
Sesbania	15 - 20	20 - 30	¾
Soybean	90	60 - 120	¾ - 1½
Velvetbean	5 - 7	30	1½ - 2½
Lab Lab	40	70 - 120	¾ - 1½
Non-legumes			
Sorghum sudangrass	20 - 30	35 - 40	½ - 1
Sudangrass	20 - 25	30 - 40	1 - 2
Japanese Millet	10 - 15	5 - 7[3]	½ - 1½
Pearl Millet	15 - 20	20 - 25 or 6 - 10[3]	½ - 1½
German Foxtail Millet	10 - 15	5 - 7[3]	½ - 1½
Buckwheat	60		½
Mixtures			
J. Millet/Soybean		15/55	1 - 1½
Cowpea/S. Sudangrass		50/10	1 - 1½

[1]If broadcasting seed or planting late in the fall, use the higher rate.